**Problem Set 2. Ecosystem Energy and Water Balances NAME:\_\_\_\_\_\_\_\_\_\_\_\_**

Turn in your responses as a word document including all your plots by 11:59PM **28 Aug, 2020.**

Today, our instructor is Dr. Jinyan Yang, a postdoctoral researcher at HIE. He will guide you through the basics of running program R and using it to compare two days of data from the nearby Cumberland Plains eddy covariance tower. These days had contrasting conditions that will help you understand partitioning of available energy. Other resources include your text and a neat animation at <https://earthobservatory.nasa.gov/global-maps/CERES_NETFLUX_M>

**Step 1**. Install R, and then Rstudio, on your computer. This free program is used worldwide for analysing many different types of data. The R software contains all the code to do the analyses, and Rstudio provides a nice user interface. There are lots of specialized “packages” within R to do certain types of analyses, including some developed by our own researchers. However, you will not need to use any packages for this exercise. Here is a quick guide for installing R and Rstudio: <https://www.datacamp.com/community/tutorials/installing-R-windows-mac-ubuntu>.

**Step 2**. Open a word document that will contain your plots and their descriptions, or save this document as a starting point for your responses. Open the R project file that has been shared with you. Also save an R script on your own hard drive that you can use for all the calculations and plotting in this exercise. Follow the basic steps of defining a dataframe, and become familiar with the dataframe structure, the variables included, and some basic statistics that R can calculate for you.

**Step 3**. Calculate the average albedo as Fsu/Fsd for both days. What happens at night? Does this make sense? NO! You need to subset your data! What is the average for each day? Why could it differ between summer and winter?

**Step 4a**. Calculate the net radiation from the component radiation, calculated from the 4-component radiometer, and define this new variable as Fnet = (Fsd+Fld)-(Fsu+Flu).

**Step 4b**. Plot Fnet and the shortwave and longwave components vs. time for both days to check that your data are looking good. Export and copy your plots to your word document.

**Step 4c**. Compare the net radiation (Fnet from step 4) with the turbulent fluxes measured by the eddy covariance sensors. Plot Fnet, Fh, Fe, and Fg vs. time on one graph for each day, using a y-axis scale that allows easy comparison. Set an appropriate y-axis label and copy your plots to your word document.

**Step 4d**. Describe the patterns you see in plots from 4b and 4c. In words, compare the components of the radiation and the individual energy fluxes (Fnet, Fe, Fh, Fg) between summer and winter. Which components change a lot, and which don’t? What happens at night?

**Step 5a**. Show how latent heat flux (Fe, in units W m-2) can be converted to evapotranspiration (ET, in units of mm/30min) with the information in note 1. Use pen and paper (or the equation editor) to demonstrate the unit conversion from energy to length units; take a photo of your dimensional analysis and insert that into your word document.

**Step 5b**. Define the new variable ET from LE in your R dataframe for each 30-min period (mm per half hour). What is the total water loss for each day in mm? How does this compare with restricting your ET estimates to daytime data only? What factors might explain the differences in ET between the two dates?

**Step 6.** Write a short (200-word) essay on what might happen to the energy and water fluxes in a warmer, drier climate or during a heat wave?

**NOTES**:

1) To convert Fe (also known as LE, latent heat flux) to ET (evapotranspiration), remember at 20°C, (latent heat of vaporization) is 2.45 MJ/kg. In other words, 2.45 MJ are needed to vaporize 1 kg or 0.001 m3 of water. Assume 1 m2 basis, and density of water of 1000 kg/m3. Also remember 1W = 1 J/s

**Table showing abbreviations and units**

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| Abbr | Variable details | Units |
| Fe | Latent heat flux (aka LE) | W m-2 |
| Fg | Soil heat flux | W m-2 |
| Fh | Sensible heat flux (aka H) | W m-2 |
| Fsd | Solar downwelling radiation | W m-2 |
| Fsu | Solar upwelling radiation | W m-2 |
| Fld | Longwave downwelling radiation | W m-2 |
| Flu | Longwave upwelling radiation | W m-2 |
| RH | Relative humidity | % |
| Ta | Air temperature | C |
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